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STUDIES IN MILK SECRETION. XIV.

The Effect of Age on the Milk Yields and Butter-Fat Percentages of Guernsey Advanced Registry Cattle.

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BULLETIN 311

STUDIES IN MILK SECRETION. XIV.

The Effect of Age on the Milk Yields and Butter-Fat Percentages of Guernsey Advanced Registry Cattle.[1]

By John W. Gowen.

SUMMARY

This paper presents a study of some phases of the problem of the relation of age to the milk yield and butter-fat percentage of Guernsey Cattle on 365-day Advanced Registry tests. Ten thousand six hundred and forty-four records are analyzed in this paper. The equations are determined for the relation of age at the commencement of test to the milk yield or butter-fat percentage of the cow.

The data shows that milk yield rises at an ever decreasing rate as the age of the cow increases until the age of maximum production is reached, 8.77 years. From this age of maximum production the milk yield declines at an ever increasing rate as the age increases.

The butter-fat percentage shows a slight but significant decline as the age of the cow advances. This decline on the average amounts to about three-tenths of one per cent in the ten years from two to twelve years old.

Tables are presented to enable the reader to determine the eight-year milk yield or butter-fat percentage of a cow of different production at other ages, assuming the conditions under which the test is made, to be the same as those for the Advanced Registry test.

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[1]Paper from the Biological Laboratory of the Maine Agricultural Experiment Station No. 160. This paper is one of a series of investigations in animal husbandry the continued prosecution of which has been made possible by a grant to the author from the Rockefeller Institute for Medical Research.

In the "Report of Progress on Animal Husbandry Investigations in 1919"[2] the writer presented an equation for the relation of age to the milk yield of Guernsey Advanced Registry cattle. Since that time much water has flowed under our bridges, widening the rift in the dam of ignorance. More than double the number of records are now available. In the work at this laboratory we have carefully searched these records for errors and discrepancies. The records are, on the whole, surprisingly accurate. One difference in method of calculating the butter-fat percentage is noticeable in the early records versus those recorded later. Where the records did not come to the same answer these records have been recalculated so that they are now all comparable and on the same basis as those now recorded. A result differing from that derived from the older equation of 1919 has been the change in the age of maximum milk yield. This age has moved toward the younger cows. The shape of the curve has changed slightly making it conform more nearly to that found for the other breeds.

The requirements for entry in the Guernsey breed are the same as those which have been in vogue for the other breeds, 250.5 to 360 pounds of butter-fat depending on the age of the cow. Table 1 shows the correlation surface for the 365-day milk yield and age of the cow at the time of commencing her test. The correlation table shows clearly that the surface is skew similar to that found for the other breeds of cattle.

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[2]Gowen, John W. 1919. Report of Progress on Animal Husbandry Investigations for 1919, Annual Report of the Maine Agricultural Experiment Station for 1919, pp. 249-284. Bulletin 283.

TABLE 1.

Correlation surface showing the relation of milk yield to age at commencement of test for Guernsey Advanced Registry Cattle.

Milk Yield (365-day)

Age at Commencement of Test	4000–5000	5000	6000	7000	8000	9000	10000	11000	12000	13000	14000	15000	16000	17000	18000	19000	20000	21000	22000	23000	24000–25000	
1:6– 2:0	7	44	69	52	42	17	9	3	1													244
2:0	26	219	489	577	467	344	176	85	26	20	5	2										2436
2:6	2	74	199	300	272	203	127	66	28	6	6	1	1	1	1							1287
3:0	2	30	152	233	211	160	107	68	31	14	10		1	1								1020
3:6		13	86	167	190	188	123	73	66	16	9	3	4		1							939
4:0		6	46	139	176	140	118	86	60	22	11	10	4	1								810
4:6		1	35	80	159	116	94	84	55	37	16	11	4	1								693
5:0			7	52	108	100	90	55	57	36	11	13	5	1	1		1					537
5:6		1	9	44	90	103	90	64	46	35	13	4	3	1	1							504
6:0			6	45	69	86	74	78	41	20	9	13	4	5	2	3						455
6:6		1	5	27	77	75	62	46	41	15	15	7	4	1	1	1						378
7:0			4	15	43	55	63	45	23	13	12	8	5	3	3							292
7:6			5	14	33	46	47	29	26	9	7	2	9	2	1							230
8:0			3	14	24	35	42	25	22	22	8	6	2	1								204
8:6			1	11	17	22	25	23	13	8	7	3	3								1	134
9:0			1	8	23	28	22	17	15	10	4	4	3	1		1						137
9:6			3	9	12	23	19	14	7	8	9	4		1								109
10:0				7	12	11	13	8	9	4	2	3	2									71
10:6			2	2	8	9	6	2	9	2	3			1								44
11:0			1	3	5	8	5	4	4	1	2			1								34
11:6			1	2	5	7	5	2	3		1											26
12:0				1	2	4	4	3	1	1			1									17
12:6				1	1	7			1	1	1											12
13:0			1	2	3	4		2	1	1												14
13:6				1	3	1	1		1													7
14:0					1	1	1															3
14:6												1										1
15:0				2	1			1														4
15:6																						
16:0																						
16:6					1																	1
17:0																						
17:6–18:0				1																		1
	37	389	1125	1800	2055	1793	1323	883	587	301	161	95	55	22	11	5	1				1	10644

The correlation surface showing the relation of the butter-fat percentages of these cows to their age at commencement of test is given in table 2. The butter-fat percentages are all for 365-day lactation records.

TABLE 2.

Correlation surface showing the relation of 365-day butter-fat percentage to age at commencement of test for Guernsey Advanced Registry cattle.

Age at Commencement of Test	Butter-Fat Percentage (365-Day)																		
	3.6–3.8	3.8	4.0	4.2	4.4	4.6	4.8	5.0	5.2	5.4	5.6	5.8	6.0	6.2	6.4	6.6	6.8	7.0–7.2	
1:6– 2:0		1	3	13	21	33	27	41	39	29	17	11	6	1	2				244
2:0	3	6	43	128	218	333	378	367	360	285	170	80	35	18	8	3		1	2436
2:6	1	4	26	64	96	185	200	231	197	120	77	40	25	12	7	1		1	1287
3:0		8	16	49	89	129	171	158	126	117	86	43	13	6	6	2	1		1020
3:6		4	15	36	82	134	153	158	129	90	57	38	24	13	4	1	1		939
4:0	1	5	14	36	70	115	137	123	114	78	58	34	12	11	1			1	810
4:6	1	8	20	43	61	103	97	106	101	80	32	23	6	7	2	2	1		693
5:0		3	20	39	66	71	88	66	70	57	29	14	5	9					537
5:6	2	2	13	22	63	68	89	80	73	42	27	13	5	4	1				504
6:0		2	12	32	61	66	80	79	44	41	20	10	8						455
6:6		3	9	26	40	49	65	72	43	34	13	13	5	3	3				378
7:0		3	9	22	36	47	42	54	35	18	16	5	3	1	1				292
7:6		1	11	18	25	34	31	39	30	20	7	8	3	1	2				230
8:0		4	7	16	31	32	28	37	21	10	5	6	5	1	1				204
8:6		2	4	13	20	18	26	21	21	3	4	2							134
9:0		1	3	10	23	20	24	17	19	13	4		1		2				137
9:6	1		6	11	17	9	24	16	13	5	5	2							109
10:0	1	1	3	4	10	14	9	11	9	5	3				1				71
10:6		1	4	3	6	8	8	4	7		1	1	1						44
11:0		1	3	3	5	4	6	4	4	1		2	1						34
11:6			2	2	3	4	4	4	5	1	1								26
12:0			1	1	2	3	3	3	1	2	1								17
12:6		1	1		1	2	3	1		2		1							12
13:0	1		1		2	6		2	1	1									14
13:6					1		2		2	1		1							7
14:0							3												3
14:6						1													1
15:0						1		1	1		1								4
15:6																			
16:0																			
16:6					1														1
17:0																			
17:6–18:0							1												1
	11	61	246	591	1050	1489	1699	1695	1465	1055	634	347	158	87	41	9	3	3	10644

The means, standard deviations, coefficients of variation, and correlation coefficients for tables 1 and 2 are given in table 3.

The average milk yield and butter-fat percentage for each age at commencement of test are also given in table 3.

TABLE 3.

Mean 365-day milk yields and butter-fat percentages of Guernsey Cattle at different ages.

Physical Constant	Milk Yield (pounds)	Age (years)	Butter-fat Percentage
Mean	9255±15	4.31±.01	5.040±.003
Standard Deviation	2255±10	2.21±.01	.481±.002
Coefficient of variation	24.4±.1	51.3 ±.3	9.5 ±.1
Correlation coefficient	Age and milk yield .412±.005		Age and butter-fat percentage —.116±.006

Age at Test	Mean	
	Milk Yield	Butter-fat Percentage
1 year 6 months to 1 year 11 months	7262	5.11
2 years 0 months to 2 years 5 months	8942	5.07
2 years 6 months to 2 years 11 months	8453	5.07
3 years 0 months to 3 years 5 months	8710	5.09
3 years 6 months to 3 years 11 months	9284	5.09
4 years 0 months to 4 years 5 months	9637	5.07
4 years 6 months to 4 years 11 months	9975	5.03
5 years 0 months to 5 years 5 months	10390	4.98
5 years 6 months to 5 years 11 months	10321	5.00
6 years 0 months to 6 years 5 months	10598	4.96
6 years 6 months to 6 years 11 months	10450	5.00
7 years 0 months to 7 years 5 months	10812	4.94
7 years 6 months to 7 years 11 months	10709	4.97
8 years 0 months to 8 years 5 months	10887	4.91
8 years 6 months to 8 years 11 months	10910	4.86
9 years 0 months to 9 years 5 months	10829	4.93
9 years 6 months to 9 years 11 months	10766	4.87
10 years 0 months to 10 years 5 months	10739	4.89
10 years 6 months to 10 years 11 months	10636	4.82
11 years 0 months to 11 years 5 months	10471	4.85
11 years 6 months to 11 years 11 months	9923	4.88
12 years 0 months to 12 years 5 months	10677	4.91
12 years 6 months to 12 years 11 months	10250	4.88
13 years 0 months to 13 years 5 months	9571	4.71
13 years 6 months and above	9441	5.05

The mean milk yield of these Guernsey cows is about 6000 pounds less than the mean milk yield found for the Holstein-Friesian advanced registry cows.[3] The standard deviation of milk yield is nearly 1800 pounds of milk less than that for the Holstein-Friesian cattle. The coefficients of variation are practically identical. The correlation coefficient for the milk yields and ages at the commencement of the tests is practically identical with that found for the Holstein-Friesian group. This correlation coefficient does not show the true relation of milk yield to age. The regression line given in table 3 is distinctly skew following closely the logarithmic type. Milk yield is, then, even more dependent on age than is apparent from the correlation coefficient of table 3.

The mean age of these Guernsey cows is nearly a fourth of a year less than the mean age of cows in the Holstein-Friesian Advanced Registry. The standard deviations for age are practically the same in the two breeds.

The mean butter-fat percentage of the Guernseys is over 1.6 per cent more than that for the Holstein-Friesian. The standard deviation of this butter-fat percentage is 1.72 more than that for the Holstein-Friesian cows. The coefficient of variation for the Guernsey cows is slightly more than that for the Holstein-Friesian cows. The coefficient of correlation for butter-fat percentage and age is almost twice that for the Holstein-Friesian Advanced Registry cattle.

The lower part of table 3 gives the average milk yield for each age. From these data we can obtain the equation describing the relation that age has to the milk yields of these Advanced Registry cows. This equation is

$$\textit{Mean milk yield} = 6372.6 + 827.9a - 51.8a^2 + 1394.6 \log (a - 1.25)$$

Where the age (a) is in years and the origin is zero years.

Figure 3 shows the observational curve and the fitted curve for the mean milk yields for each age. The ordinates are the pounds of milk produced and the abscissae are the ages. The curve fits the observations very well.

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[3]Gowen, John W. 1920. Studies in Milk Secretion. VIII. On the Influence of Age on Milk Yield and Butter-Fat Percentage as determined from the 365-day records of Holstein-Friesian cattle. In Annual Report of the Maine Agricultural Experiment Station for 1920. pp. 185-196. Bulletin 293.

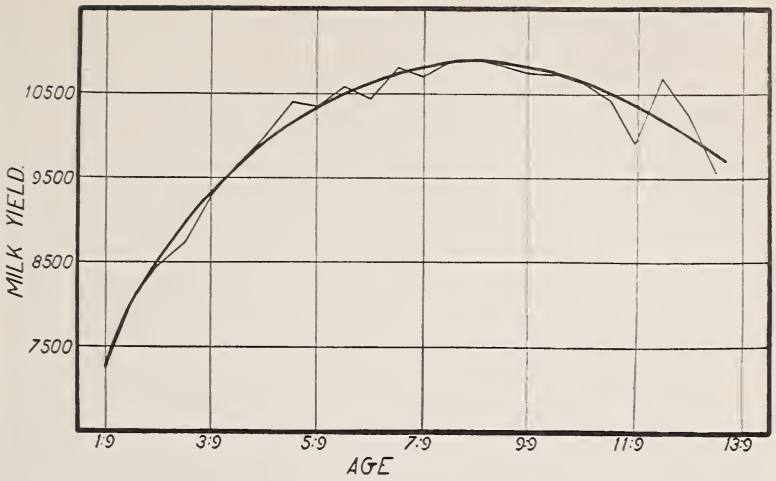

FIG. 3. Observational and fitted curves showing the relation of the 365-day milk yield to age for Guernsey cattle. The observational curve is the rough curve and the smooth curve is the curve determined from the equation given in the text.

We may differentiate this equation to determine the age of maximum productivity. When this is done we find the age of maximum producing capacity to be 8 years 9.24 months.

Any data on the relation of age to milk yield brings up the question of what is a suitable requirement for Advanced Registry. The present linear increase from 2 years to 5 years is obviously unfair to a number of cows. A much more reasonable requirement would be based on the average performance of all the Guernsey cows, Advanced Registry or not, for the different ages. It is extremely unfortunate that we do not have a record for every registered cow so that the true mean curve of milk yield and butter-fat percentage for age could be determined. What is more important still, this information could then be used, together with a proper understanding of the inheritance of milk yield, to breed intelligently for producing offspring of high milk yield. Barring this method, through lack of information, the next reasonable requirement would seem to be based on the mean curve for milk yield as given in figure 3. If we are to have a requirement this gives a true physiological basis for it, instead of the present arbitrary one lacking any foundation. However, the author hopes to see the day when the re-

quirements will be dropped and registered cattle will come to mean recorded cattle, for the economics of milk production requires records on all cattle, good or bad, to properly utilize knowledge of milk inheritance in breeding for increased milk yield.

The third column of table 3 gives the mean butter-fat percentages for each age of test for these Guernsey cattle. These means are shown as the observational curve of figure 4. The points obviously lie in a straight line. The equation to this line may be obtained from the means and standard deviations of table 3. The equation is

$$\textit{Butter-fat percentage} = 5.147 - .025\ \textit{Age}$$

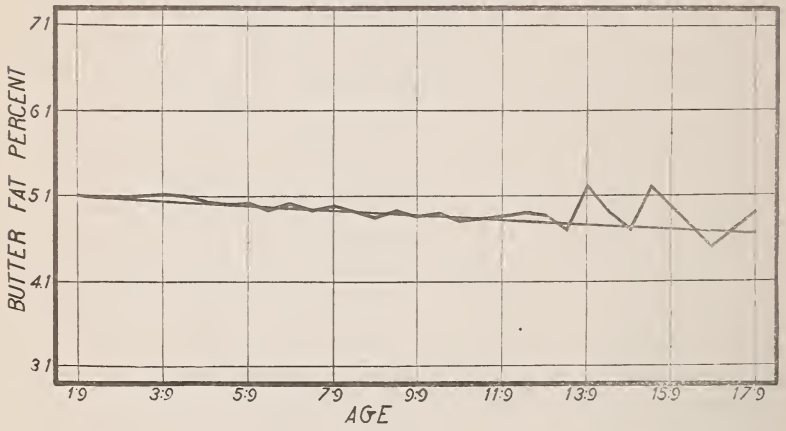

FIG. 4. Observational and fitted curve showing the relation of 365-day butter-fat percentage to age in Guernsey cattle. The observational curve is represented by the rough line and the fitted curve by the straight line.

Figure 4 shows the observational and fitted curves. The figure shows clearly that there is a slight decline in butter-fat percentage as the age of the cow increases.

From these data we are in a position to make a suitable correction of milk yield or butter-fat percentage for age of Guernsey cows based on the average performance of these cows as analyzed above. This method is open to some criticisms but so are the others. There is also the method of correcting the

records by suitable equations determined from the relation of one lactation to another. This method, however, is open to two serious objections if a large series of records are to be corrected to a standard age, first the assumption of a very rapid rise in the correlations to the standard age from the ages first preceding and following the age to which correction is made and second the skew character of the regression and scedastic curves. For these reasons we have standardized on the mean curves as the basis for the correction of records for age when used in progeny performance and inheritance studies in this laboratory.

It is of interest to see what these age corrections mean in terms of milk yield and butter-fat percentage. Table 4 presents briefly some data to indicate how age affects milk yield. The left hand side of the table gives the ages when the tests were made. The top line gives the milk yield of the cow at the time of test. In this column and beside the proper age is found the probable milk yield of these cows at 8 years on the basis of mean regression lines.

TABLE 4.

Milk Yields of Guernsey Advanced Registry cows corrected to an 8 year basis.

Age in Years	Milk Yield at Given Age														
	4000	5000	6000	7000	8000	9000	10000	11000	12000	13000	14000	15000	16000	17000	18000	19000
	Milk Yield at 8 Years															
1.75	5984	7481	8977	10473	11969	13466	14960	16450	17954	19451	20947	22443				
2.00	5668	7085	8503	9920	11337	12754	14171	15589	17006	18423	19840	21257				
2.50	5251	6564	7877	9190	10503	11816	13129	14442	15755	17068	18381	19694	21007	22320		
3.00	4966	6207	7449	8690	9932	11173	12415	13656	14898	16139	17381	18622	19864	21105		
3.50	4749	5936	7124	8311	9499	10686	11873	13061	14248	15436	16623	17810	18998	20185		
4.00	4578	5723	6867	8012	9156	10301	11446	12590	13735	14879	16024	17169	18313	19458	20602	
4.50	4440	5550	6660	7770	8880	9990	11100	12210	13320	14430	15540	16650	17760	18870	19980	
5.00	4327	5409	6490	7572	8654	9736	10818	11900	12981	14063	15145	16227	17308	18390	19472	20554
5.50	4235	5293	6352	7411	8470	9529	10587	11646	12705	13764	14823	15881	16940	17999	19058	20116
6.00	4160	5200	6240	7281	8321	9361	10401	11441	12481	13521	14562	15602	16642	17682	18722	19762
6.50	4101	5126	6151	7177	8202	9227	10252	11278	12303	13328	14354	15379	16404	17430	18455	19480
7.00	4055	5069	6083	7097	8110	9124	10138	11152	12166	13180	14193	15207	16221	17235	18249	19263
7.50	4021	5027	6032	7038	8043	9049	10054	11060	12065	13071	14076	15082	16087	17093	18098	19104
8.00	4000	5000	6000	7000	8000	9000	10000	11000	12000	13000	14000	15000	16000	17000	18000	19000
8.50	3989	4986	5983	6980	7978	8975	9972	10969	11967	12964	13961	14958	15956	16953	17950	18947
9.00	3988	4985	5982	6980	7977	8974	9971	10968	11965	12963	13960	14957	15954	16951	17948	18945
9.50	3998	4998	5998	6997	7997	8997	9996	10996	11996	12995	13995	14995	15994	16994	17994	18993
10.00	4019	5024	6028	7033	8038	9043	10048	11052	12057	13062	14067	15072	16076	17081	18086	19091
10.50	4050	5063	6075	7088	8101	9113	10126	11138	12151	13164	14176	15189	16202	17214	18227	19240
11.00	4092	5116	6139	7162	8185	9209	10232	11255	12278	13302	14325	15348	16371	17395	18414	19441
11.50	4147	5184	6220	7257	8294	9331	10368	11404	12441	13478	14515	15552	16588	17625	18662	19699
12.00	4214	5267	6321	7374	8428	9481	10535	11588	12642	13695	14749	15802	16856	17909	18963	20016

In this table we note that a cow giving 11000 pounds (top line) as a 2 year old would, on the basis of the curve for average milk yield produce an equivalent to 15589 pounds of milk (in 11000 column, 2.00 row) as an 8 year old. Similarly a cow producing 12000 pounds as a 12 year old would have a production equivalent to a little more than this milk yield as an eight year old, 12642 pounds of milk. In the same manner some idea of the probable milk yield of a cow at approximately maximum form may be gained from examination of this table. The prediction is probably not as accurate for the extreme producers as it is for those whose milk yield is more nearly average.

It is of interest to take the records of one of these high producers and determine how well these tables for milk yield apply to her records. Murne Cowan, 19597, has three records for advanced registry. Each record is for the year period. The first record is for 16,729 pounds of milk at 6 years 3 months of age. The second record is for 24,008 pounds of milk at 8 years 9 months of age. The third record is for 17,384 pounds of milk at 11 years 1 month of age. If we examine table 4 we note that in the six year age row, at 17,000 pounds of milk (column 15) the expected production of this cow at 8 years would be 17,682 pounds instead of the 24,008 pounds she actually produced. In other words her production was 6326 pounds more than was expected. Before considering this difference let us examine the third record. Figure 3 shows that, on the average, the cows at 11 years 1 month produce slightly more milk than those at 6 years 3 months. The 6 year 3 month record of Murne Cowan would consequently predict a record of about 17,000 pounds at 11 years 1 month old or a record closely similar to that actually made. This illustration brings out a true biological fact concerning milk records. The phenomenal record is made under such pressure that every condition surrounding the cow and the cow herself must be in the most favorable condition. Furthermore the most favorable conditions for one cow may not be favorable to another so that it is extremely hard to duplicate the conditions which are favorable. The high records tend to be made when the cow and surroundings are in the pink of condition for making high records, the low records when the conditions are unfavorable. There is a tendency for high and low record cows when retested to have their records regress toward the average of the

breed due to the change in conditions surrounding the cow. The correction on the basis of the mean curve takes no cognizance of the environmental conditions but assumes that the conditions remain as they were in the first test. The method of correlations as given elsewhere[4] takes the changing conditions into account. Both methods have their uses.

In view of these facts, as illustrated by the records of Murne Cowan, what is the probable error within which we might expect the record of any one cow. The standard deviation of milk yield offers a means of determining this range. The standard deviation of the milk yields of 8 year old cows is 2335 or the approximate probable error is .67449 x 2335 or 1575, or for any determination found in table 4 it is about an even chance that the actual milk yield of the cow will be within 1600 pounds either side of the figure shown. Thus for Murne Cowan's 6 year old milk yield the probable 8 year production was 17,682±1575 and the 11 year old milk yield predicted 17,695±1575 for the 8 year old production. In her phenomenal record this cow produced much over this mark. In fact it may be shown that there is only one chance in over 25,000 that a cow would make such a record as she actually did. We already know that she is at least not more than one cow in 10644 which could.

From table 5 we note that a cow giving a milk testing 5.0 per cent as a 2 year old would be equivalent to a cow having a test of 4.85 at 8 years. Similarly a cow testing 5.25 at 10 years old would be equivalent to one testing a little higher at 8 years, 5.30 per cent. The difference for the butter-fat percentages at the different ages are in no case large amounting in general to less than a quarter of one per cent.

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[4]Gowen, John W. 1923. Studies in Milk Secretion X. Relation between the milk yield of one lactation and the milk yield of a subsequent lactation in Guernsey Advanced Registry cattle. In Jour. Dairy Science. Vol. VI, No. 2, pp. 102-121.

————————1923. Studies in Milk Secretion XI. Relation between the butter-fat percentage of one lactation and the butter-fat percentage of a subsequent lactation in Guernsey Advanced Registry cattle. In Jour. Dairy Science. Vol. VI, No. 4, pp. 330-346.

TABLE 5.

Butter-fat Percentage of Guernsey Advanced Registry cows corrected to an 8 year basis.

Age in Years	Butter-fat Percentage at Given Age																
	3.00	3.25	3.50	3.75	4.00	4.25	4.50	4.75	5.00	5.25	5.50	5.75	6.00	6.25	6.50	6.75	7.00
	Butter-fat Percentage at 8 Years																
1.75	2.91	3.15	3.39	3.63	3.87	4.12	4.36	4.60	4.85	5.09	5.33	5.57	5.82	6.06	6.30	6.54	6.78
2.00	2.91	3.15	3.40	3.64	3.88	4.12	4.37	4.61	4.85	5.09	5.34	5.58	5.82	6.07	6.31	6.55	6.79
2.50	2.92	3.16	3.41	3.65	3.89	4.13	4.38	4.62	4.86	5.11	5.35	5.59	5.84	6.08	6.32	6.57	6.81
3.00	2.93	3.17	3.41	3.66	3.90	4.14	4.39	4.63	4.88	5.12	5.36	5.61	5.85	6.09	6.34	6.58	6.83
3.50	2.93	3.18	3.42	3.67	3.91	4.16	4.40	4.64	4.89	5.13	5.37	5.62	5.87	6.11	6.35	6.60	6.84
4.00	2.94	3.18	3.43	3.68	3.92	4.17	4.41	4.66	4.90	5.15	5.39	5.64	5.88	6.13	6.37	6.62	6.86
4.50	2.95	3.19	3.44	3.68	3.93	4.18	4.42	4.67	4.91	5.16	5.41	5.65	5.89	6.14	6.39	6.63	6.88
5.00	2.96	3.20	3.45	3.69	3.94	4.19	4.43	4.68	4.93	5.17	5.42	5.66	5.91	6.16	6.40	6.65	6.90
5.50	2.96	3.21	3.45	3.70	3.95	4.20	4.44	4.69	4.94	5.18	5.43	5.68	5.92	6.17	6.42	6.66	6.91
6.00	2.97	3.22	3.47	3.71	3.96	4.21	4.46	4.70	4.95	5.20	5.45	5.69	5.94	6.19	6.44	6.68	6.93
6.50	2.97	3.22	3.47	3.72	3.97	4.22	4.47	4.71	4.96	5.21	5.46	5.71	5.95	6.20	6.45	6.70	6.95
7.00	2.99	3.23	3.48	3.73	3.98	4.23	4.48	4.73	4.98	5.22	5.47	5.72	5.97	6.22	6.47	6.72	6.97
7.50	2.99	3.24	3.49	3.74	3.99	4.24	4.49	4.74	4.99	5.24	5.49	5.74	5.99	6.24	6.48	6.73	6.98
8.00	3.00	3.25	3.50	3.75	4.00	4.25	4.50	4.75	5.00	5.25	5.50	5.75	6.00	6.25	6.50	6.75	7.00
8.50	3.01	3.26	3.50	3.76	4.01	4.26	4.51	4.76	5.01	5.26	5.51	5.76	6.01	6.27	6.51	6.77	7.02
9.00	3.02	3.27	3.52	3.77	4.02	4.27	4.52	4.77	5.03	5.28	5.53	5.78	6.03	6.28	6.53	6.78	7.04
9.50	3.02	3.28	3.53	3.78	4.03	4.28	4.53	4.79	5.04	5.29	5.54	5.79	6.05	6.30	6.55	6.80	7.05
10.00	3.03	3.28	3.54	3.79	4.04	4.29	4.55	4.80	5.05	5.30	5.56	5.81	6.06	6.32	6.57	6.82	7.07
10.50	3.04	3.29	3.55	3.80	4.05	4.31	4.56	4.81	5.06	5.32	5.57	5.82	6.08	6.33	6.58	6.84	7.09
11.00	3.05	3.30	3.55	3.81	4.06	4.32	4.57	4.82	5.08	5.33	5.59	5.84	6.09	6.35	6.60	6.86	7.11
11.50	3.05	3.31	3.56	3.82	4.07	4.33	4.58	4.84	5.09	5.35	5.60	5.85	6.11	6.36	6.62	6.87	7.13
12.00	3.06	3.32	3.57	3.83	4.08	4.34	4.59	4.85	5.10	5.36	5.61	5.87	6.12	6.38	6.64	6.89	7.15

The problem for the butter-fat percentage is much the same as that for the milk yield. Murne Cowan's first 365-day milk record had a butter-fat test of 5.05 per cent. Her second test was for 4.57 per cent and her third test was 4.55 per cent. If we examine table 5 the 6 year old test, 5.05 per cent. calls for a butter-fat test of 5.00 for the eight year age. The actual test as noted above was 4.57 or a difference of .43 per cent. The eleven year old test calls for an 8 year old test of 4.62 or a difference of .05 per cent from the actual. The differences in the butter-fat percentages are undoubtedly to be accounted for by temporary environmental differences surrounding the tests. Some estimate must be had of these differences and the part they play in the variation of the butter-fat percentage. This may be obtained from the standard deviation of the butter-fat percentage. The probable error or range between which fifty out of every one hundred cows will be found is approximately equal to .67449 x .481 or .324. In other words for each predicted test there is an equal chance that the actual record will be within the range .324 below the predicted test or .324 above the predicted test.

The Mathematical Handling of Breeding Data.

All investigations and inquiries that involve numbers require more or less mathematical handling. Where the data involved are few an arithmetical mean or average is all that is required. For instance in the chemical analysis of a fertilizer rarely more than two or at the outside three determinations are involved. Hence adding these together and dividing by the number of determinations gives the average. On the other hand in plant and animal breeding work where hundreds or even thousands of units of data are included the handling involves not merely arithmetical but logarithmic methods.

While the problems of agriculture may, in general, be stated in simple terms and the answers to the data analyzing these problems may be equally simply stated, the same is by no means true with the steps necessary to analyze and obtain correct answers to them. In publication of the results of those biological investigations that involve such mathematical analysis, the Maine Agricultural Experiment Station is embarrassed by the question of how far the steps in handling the data upon which the conclusions rest should be included in the papers designed primarily for the men who are leaders in the practical agriculture in the State.

In all such publications, an attempt is made to present in clear, non-technical language, the essential facts and conclusions. This is for the most part included in the summary at the beginning bulletin. At the same time it seems necessary to include in the text enough of the technical, analytical steps to enable the practical man to go deeper into the subject, if he desires. Further, sufficient data should be included to enable other investigators in the same field to make comparisons with their own work and to check conclusions.

Frequently the terms used are new and therefore unusual, for the technique of handling such data is, of itself, new. However, it may not be many years before most of these terms will be as well understood as those used in reporting analyses of feeding stuffs and fertilizers. In the mean time the Station realizes that the practical agriculturist, who wishes to get a better understanding of the fundamentals of such work, will find difficulty in securing satisfactory definitions in many dictionaries, of the terms used. Therefore, with the hope of assisting in making this information available, a glossary of terms used in handling such data has been prepared. A copy of this will be sent on request to the Station.